

Cover Page

BARD Project Number: IS-3517-04

Date of Submission of the report: August 31, 2008

Project Title: Effects of Soil Properties and Organic Residues Management on C Sequestration and N Losses.

Investigators

Institutions

Principal Investigator (PI):

Asher Bar-Tal

A.R.O. The Volcani Center

Co-Principal Investigator (Co-PI):

Paul R. Bloom

University of Minnesota

Collaborating Investigators:

Jean-Alex E. Molina

University of Minnesot

C. Edward Clapp

University of Minnesota

Pinchas Fine

A.R.O. The Volcani Center

Aviva Hadas

A.R.O. The Volcani Center

Rodney T. Venterea

USDA-ARS University of Minnesota

Dong Chen

University of Minnesota

Dan Zohar

SHAHM Ministry of Agriculture

Keywords *not* appearing in the title and in order of importance. Avoid abbreviations. Carbon Sequestration, Carbonates, Ammonium volatilization, Organic Wastes, Decomposition, Roots, ¹³C, ¹⁵N, NCSOIL, NCSWAP,

Abbreviations commonly used in the report, in alphabetical order:

C– Carbon, CEC - Cation exchange capacity, DOC – Dissolved organic carbon, DM – Dry matter, N – Nitrogen, NCSOIL – A model that simulates N and C in soil-residue system, NCSWAP – A model that simulates organic residues-soil-water-plant system, OW - Organic waste, OM – Organic matter, PM – Poultry manure, PMC - Poultry manure compost, SOM – Soil organic matter, SOC – Soil organic carbon, USEPA – United States environment protection agency

Budget: IS: \$ 168,500

US: \$ 171,500

Total: \$ 340,000

Signature
Principal Investigator

Signature
Authorizing Official, Principal Institution



Final Scientific Report

Publication Summary (numbers)

	Joint IS/US authorship	US Authors only	Israeli Authors only	Total
Refereed (published, in press, accepted) BARD support acknowledged		1		1
Submitted, in review, in preparation	2	2	2	6
Invited review papers				
Book chapters				
Books				
Master theses		1 (in preparation)		
Ph.D. theses			1 (in preparation)	1
Abstracts	1	2	1	4
Not refereed (proceedings, reports, etc.)			2	2

Postdoctoral Training: List the names and social security/identity numbers of all postdocs who received more than 50% of their funding by the grant.

Dong Chen University of Minnesota 618-78-3450

Yi Zhang University of Minnesota 609-62-2980

Hadar Heller ARO 055280184

Cooperation Summary (numbers)

	From US to Israel	From Israel to US	Together, elsewhere	Total
Short Visits & Meetings	1	2		
Longer Visits (Sabbaticals)				

Description Cooperation:

The Israeli and US teams shared expertise on field and laboratory techniques and the US team did all of the analysis for soil gases (carbon dioxide, nitrous oxide and methane) as well as soil C and N stable isotope analyses for both teams. Dr. Molina of the US team provided his N and C models and expertise for the Israeli incubation and field studies. Dr Hadas and Dr Bar-Tal of the Israeli team provided their experience with soil models for further development of the NCSOIL model. The Israeli team conducted all the incubation experiments using soils from both countries.

Patent Summary (numbers)

	Israeli inventor only	US inventor only	Joint IS/US inventors	Total
Submitted				
Issued (allowed)				



Final Scientific Report

Licensed				
----------	--	--	--	--

Abstract

Objectives - The overall objective of this proposal was to explore the effects of soil properties and management practices on C sequestration in soils and off-site losses of N. The specific objectives were: 1. to investigate and to quantify the effects of soil properties on C transformations that follow OW decomposition, C losses by gaseous emission, and its sequestration by organic and mineral components of the soil; 2. to investigate and to quantify the effects of soil properties on organic N mineralization and transformations in soil, its losses by leaching and gaseous emission; 3. to investigate and to quantify the effects of management practices and plants root activity and decomposition on C and N transformations; and 4. to upgrade the models NCSOIL and NCSWAP to include inorganic C and root exudation dynamics. The last objective has not been fulfilled due to difficulties in experimentally quantification of the effects of soil inorganic component on root exudation dynamics. Objective 4 was modified to explore the ability of NCSOIL to simulate organic matter decomposition and N transformations in non- and calcareous soils.

Background - Rates of decomposition of organic plant residues or organic manures in soil determine the amount of carbon (C), which is mineralized and released as CO₂ versus the amount of C that is retained in soil organic matter (SOM). Decomposition rates also greatly influence the amount of nitrogen (N) which becomes available for plant uptake, is leached from the soil or lost as gaseous emission, versus that which is retained in SOM. Microbial decomposition of residues in soil is strongly influenced by soil management as well as soil chemical and physical properties and also by plant roots via the processes of mineral N uptake, respiration, exudation and decay.

Major conclusions and achievements –

When a low C/N ratio waste like pasteurized chicken manure (PCM) is added to a row crop like corn in the Mediterranean climate of Israel, even at very high rates, the carbon is evolved rather rapidly as CO₂ and little remains to contribute to SOM. This contrasts with the addition of high C/N corn stover residue for which a much lower fraction of C is lost as CO₂. In irrigated sweet corn the addition of high C/N residue can result sufficient N₂O release to produce twice the greenhouse gas potential compared to the CO₂ evolved from the same waste. The rate of evolution CO₂ produced by mineralization of organic matter and root activity affected by the rate of gaseous diffusion out of the profile. Soil profile data show how the CO₂ concentration increases with depth and as well as how root activity, soil moisture, addition of residues and temperature influence soil CO₂ concentrations. Infrared CO₂ sensors can be used to effectively obtain continuous CO₂ data with rapid response. Data from these sensors show the short-term peaks after rainfall illustrating the importance of soil moisture in controlling the diffusion of CO₂ from soils. A laboratory incubation study was used to obtain the data for computer modeling of the processes that result in C and N mineralization. The NCSOIL model was able to produced realistic rate parameters and good fits to the mineralization data but the dissolution of carbonate had to be included for the high carbonate soil.



Final Scientific Report

Achievements

A field of study of C and N dynamics under different residue and tillage management in sweet corn production was conducted for 3 years in a slightly calcareous soil in Israel. The treatments included the return of corn stover added at normal corn residue (CR) return rates (1.6 to 2.2 tons C ha⁻¹ y⁻¹) and pasteurized chicken manure (PCM) added at highest rate that is used by farmers (9.4-10.6 tons C ha⁻¹ y⁻¹). The CR has a C/N of 36 and the PCM has a C/N of 9. Measurement of the CO₂-C flux from the soil over 2 years showed annual emissions of 14.7, 3.1 and 2.8 tons ha⁻¹ y⁻¹ for the PCM, CR and control treatments, respectively. The difference between the plus residue and the no residue control treatments show that on average all the PCM C is evolved as CO₂. Tillage increases the flux compared to no tillage and flux is higher at higher soil moisture.

The N₂O data showed that 97.4 kg ha⁻¹ y⁻¹ of the 1000-1230 kg ha⁻¹ y⁻¹ of N added as PCM, was evolved as N₂O compared to only 3.1 and 3.2 kg ha⁻¹ y⁻¹ from the corn residue and control treatments. Given that N₂O has 296 times the greenhouse gas potential as CO₂, the effect PCM-N on global warming potential is about double the CO₂ emissions. The flux of N₂O did increase with increasing soil moisture but soil temperature had a greater effect than did soil moisture. The average total annual uptake of N by the corn crop in the PCM, CR and control treatments was 307, 247 and 221 kg ha⁻¹ y⁻¹, respectively. Thus, emission of N as N₂O is about third of the N taken up by the crop in the PCM treatment but less than 1.5% in the CR and control treatments.

The CO₂-C flux from soils under corn was also determined in Minnesota over 2 seasons. In this experiment the effect of corn root respiration and root turnover was investigated by comparing measurements in subplots with and without root exclusion barriers. As expected, the influence of temperature was much more apparent than in Israel and the CO₂ flux from late fall to late spring, when the soil temperatures were less than 10 °C, is very low. The CO₂ flux from the root exclusion (RE) sub plots generally followed the soil temperature with the maximum flux observed when the temperature at 50 cm reached a maximum of 23 °C. The CO₂ flux was much greater from the root active (RA) treatment and the maximum flux occurred during the period of most rapid corn growth. The annual emission from the RA and RE plots was 2140 and 1140 kg C ha⁻¹ y⁻¹ respectively, demonstrating the importance of root activity for CO₂ flux from soils under agricultural crops. The quantities in Israel in cropped and bare plots in the growing season were in general agreement, 1806 and 541 kg ha⁻¹ y⁻¹, respectively, while annual quantities were approximately double that of Minnesota.



Final Scientific Report

Measurements in Minnesota showed that the CO₂ concentrations below ground are very high compared to atmospheric CO₂ and that temperature and depth in the soil profile were important factors in determining concentration. The CO₂ concentrations were significantly higher in the RA subplots than in the RE subplots, with the difference more apparent at 10 and 20 cm depths than at deeper depths. The CO₂ in the RA plots at 10 cm attained values as high 12000 ppm while the maximum concentrations reached only 4000 ppm in the RE subplots. At 60 cm the highest concentrations were 20000 ppm in the RA treatment and 15000 in the RE treatment. The measurements in Israel in bare plots, throughout 1 year, showed that CO₂ increases very significantly with depth down to 50 cm. In the control plots at 10 cm the mean concentration was 3600 ppm while at 50 cm the mean concentration was 6300 ppm. Addition of PCM caused a very significant increase to 11800 ppm at 10 cm and 30700 ppm at 50 cm.

The group in Minnesota investigated the use of infrared sensors as an alternative to the discrete sampling with gas chromatographic analysis that was used in the studies described above. A short-term field study established that CO₂ sensors installed in PVC tubes with CO₂ permeable membranes can be used to effectively obtain continuous CO₂ data with rapid response to soil CO₂ (Chen et al. 2005). In a further experiment over a whole growing season the sensor data were generally comparable to the GC results, except for the very significant short-term peaks after rainfall events. This illustrates the importance of air filled porosity in the transport of CO₂ out of the soil and the role of soil water in inhibiting gaseous diffusion in soils.

The rates of C and N mineralization were determined in laboratory incubation studies with the soils from the Israel and Minnesota field studies and additional non-calcareous and calcareous Israeli soils, with and without PCM and CR. As with the field experiment the addition of corn stover had only as small effect on the CO₂ flux, but the PCM more than doubled the flux. Computation of the difference between the residue treatments and the control showed that in the Bet Dagan soil the 14 weeks of incubation resulted in oxidation of 60% of the PCM C and 35% of CR. The higher oxidation of organic C from the PCM than the CR is in agreement with the field data. The mineralization and oxidation of N resulted in high KCl extractable inorganic N, mostly nitrate N, and after 14 weeks of incubation the following quantities were obtained in the Bet Dagan soil: 200 mg⁻¹ kg⁻¹ in the control and the CR treatments and 550 mg⁻¹ kg⁻¹ in the PCM treatment.

In the incubation experiments a very significant decrease in pH was observed for all except the high carbonate Bet She'an soil. The greatest impact on pH was for the Minnesota and Golan Heights soils which had pH values <5 at the end of the incubation. In the calcareous Bet She'an soils the result was the release of excess CO₂ probably due to the dissolution carbonate. The



Final Scientific Report

NCSOIL model was able to produced realistic rate parameters and good fits to the mineralization data but the dissolution of carbonate had to be included for the Bet She'an soil.

List of publications

- Chen, D., J.A.E. Molina, C. E. Clapp, R.T.Venterea, and A.J. Palazzo. 2005 Corn root influence on automated measurement of soil CO₂ concentration. *Soil Science*, 170:779-787.
- Lee, D.T , Y. Zhang, C.E. Clapp, P.R. Bloom, D. Chen and R. R. T. Venterea. (in preparation) Comparison of IR sensor and gas chromatography determination of soil carbon dioxide concentrations at various soil depths in corn. *Communications in Soil and Plant Analysis*.
- Tamir, G., A. Bar-Tal, P. Fine, M. Shenker and H. Heller. (in preparation). Changes in Soil pH and cations composition following organic matter mineralization. *Soil Science Society American Journal*.
- Heller, H., A. Bar-Tal, G. Tamir, P. Fine and A. Hadas. (in preparation). The effects of soil properties on mineralization of organic residues. *Soil Science Society American Journal*.
- Heller, H., A. Bar-Tal, G. Tamir, R.T. Venterea, D. Chen, Y. Zhang, C.E. Clapp, P. Bloom, P. Fine. (in preparation). The effects of manure and corn residues application and no tillage cultivation on the emission of CO₂ and N₂O from a corn grown field. *Journal of Environmental Quality*.
- Zhang, Y., C.E. Clapp, Paul R. Bloom J.A.E Molina and D.T. Lee. (in preparation). Corn root influence on the soil concentration profiles and fluxes of CO₂ gas. *Soil Science*.